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Cover Picture: Hon. C. B. Sherwood, New Brunswick's Minister of Agriculture; and Dr. Ellen MacGillivray of the technical staff of the Federal Experiment Station at Fredericton, survey advance poster announcing our Annual Meeting.

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SUSTAINING MEMBERS

EFFECTS OF SEED SPACING AND FERTILIZER RATE ON FIELD PERFORMANCES OF POTATO VARIETIES AND ON FINANCIAL RETURNS[1]

G. V. C. Houghland and Robert V. Akeley[2]

Experience of potato breeders and others has shown that it is usually desirable to obtain as much information as possible on the field performance of newly-named varieties before they are released for commercial production. For this purpose the procedure described here has proved practicable and highly satisfactory. Because of certain inherent advantages, obtainable only through a combination of factorial field design and analysis of variance, the method outlined is proposed for consideration as a standard procedure for comparing the field performances of potato varieties. It is realized that in any particular experiment of this type, the choice of experimental variables such as varieties, seed-spacing distances, and fertilizer rates would have to conform with local interests, but the field design and the analysis of the data, however, would not have to be materially altered.

The varieties Saco, Kennebec, Katahdin, and Merrimack were selected for the present experiment, and these were planted at 3 different spacing distances with 4 rates of fertilizer application. The Katahdin variety, because of its well-established growth characteristics, was included as a control. The treatment effects on yield, tuber size, and number of tubers per hill were determined and, in addition, financial returns from the differential use of seed and fertilizer were calculated.

Procedure

Planting

The factorial experiment was conducted at Aroostook Farm, Presque Isle, Maine, in 1956, on a representative field of Caribou loam soil. The diagram shown in figure 1 illustrates the arrangement of the main plots, sub-plots, and ultimate 2-row plots used in one block. Three adjacent blocks similar in arrangement completed the experiment making a total of 4 replications for each treatment.

Fertilizer

One unusual feature of this field design is the plot arrangement permitting continuous application of the fertilizer entirely across each block, thus providing long narrow main plots. The fertilizer rates indicated by F-1, F-2, F-3 and F-4 in figure 1 represent, respectively, 1,000, 1,200, 1,400, and 1,600 pounds per acre of 10-15-15 analysis fertilizer. A standard type 2-row potato planter with covering disks removed was used to apply the fertilizer which was placed in bands on each side of the potato row.

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[1]Accepted for publication November 10, 1958.

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Reasonably accurate delivery of the fertilizer was obtained by calibrating the mechanism on the planter. However, it was found that accuracy of delivery could be appreciably improved by using a special belt-feed attachment.

Varieties

After the fertilizer had been applied, the field was laid out in four 30-foot sections with 3-foot intersections. The individual plots were then located by setting the proper stakes preparatory to planting. To avoid mixing the seed while planting, only one variety was planted at a time. In figure 1, V-1, V-2, V-3 and V-4 represent the varieties Saco, Kennebec, Katahdin, and Merrimack, respectively, arranged randomly within each fertilizer plot.

Seed Spacing

Planting poles marked with 6-inch, 9-inch, and 12-inch distances were used as guides to aid in getting the proper seed spacing. These spacing distances are represented in figure 1 by S-1, S-2, and S-3, respectively. In each 30-foot row 60 seed pieces were planted at the 6-inch spacing distance, 40 pieces at the 9-inch spacing and 30 pieces at the 12-inch spacing. Approximately 5 barrels of cut seed of each variety were required for the entire experiment. When planting was completed a tractor equipped with suitable ridging tools was used to cover the seed.

Harvesting

Digging

At harvest time the potatoes were dug with a standard-type 2-row digger. The plot boundaries were marked, without stopping the digger, by resetting plot stakes in the gaps in the rows of harvested potatoes caused by the unplanted 3-foot intersections.

Grading

The harvested potatoes were then run over a grader so that the weights of 2-inch minimum-grade tubers and the total weights of tubers from each plot could be obtained. Potatoes below the 2-inch grade made up less than 3 per cent of the total yield. After grading, the total number of tubers per plot were counted. From these data yields per acre in cwt were determined and the average weight of tuber and average number of tubers per hill were calculated for each variety and treatment.

Analysis of Data

Analysis of Variance

Table 1 lists the results of analysis of variance carried out on the yield data for 2-inch minimum-grade tubers:

The analysis of the yield data lists 3 appropriate error terms, each applying to one of the independent variables, or main effects. These are related to the plot groups for fertilizer rates, varieties, and seed spacings shown in the field diagram (Figure 1). All the main effects were highly significant, as indicated by their F values. Among the interactions of the variables, Spacing x Varieties was the only one statistically significant.

F-3	F-1	F-4	F-2
V-2 S-2,3,1	V-4 S-3,2,1	V-2 S-3,1,2	V-1 S-2,1,3
V-4 S-2,3,1	V-3 S-2,1,3	V-4 S-2,1,3	V-2 S-3,1,2
V-3 S-1,2,3	V-1 S-2,3,1	V-3 S-3,1,2	V-4 S-2,1,3
V-1 S-2,3,1	V-2 S-1,3,2	V-1 S-3,1,2	V-3 S-1,3,2

Note: F-1, F-2, F-3, F-4 = Fertilizer rates.
V-1, V-2, V-3, V-4 = Varieties.
S-1, S-2, S-3 = Seed Spacings.

FIGURE 1.—Plot and treatment arrangements for one replication in the experiment.

TABLE 1.—*Analysis of variance on yield data for 2-inch minimum grade potatoes.*

Source of Variation	D/F	Mean Square	F Value
Total	191	--	--
Replications	3	2,756	8.13*
Fertilizer Rates	3	30,406	89.76**
Error A	9	339	--
Varieties	3	116,291	195.33**
Var. x Fert. Rates	9	341	0.57
Error B	36	595	--
Seed Spacings	2	31,348	63.83**
Spac. x Fert. Rates	6	383	0.78
Spac. x Varieties	6	1,119	2.28*
Spac. x Var. x Fert.	18	444	0.90
Error C	96	491	--

C. V. for experiment = 6.8 per cent
*Significant at .05 level
**Significant at .01 level

Statistical significance for this interaction was also obtained when a similar analysis was conducted on the data for average weight of tuber and number of tubers per hill. The 6.8 per cent coefficient of variability for the experiment is considered satisfactory.

Results

Main Effects

Table 2 shows the specific results obtained from main effects and lists appropriate values for comparing the various yield differences at two levels of significance.

Fertilizer

The influence of fertilizer is clearly indicated by the consistent yield increases obtained from applications ranging from 1,000 pounds to 1,400 pounds per acre. The failure to get further increases in yield at the 1,600-pound rate indicates that under the prevailing conditions the limit of fertilizer use had been reached at the 1,400-pound rate.

Varieties

The relative producing ability of the 4 varieties can be judged by comparing the results listed under variety main effects. The highest average yield was produced by Saco followed by Kennebec, Katahdin, and Merrimack. All these yield comparisons are highly significant.

Seed Spacing

In general, yields were increased significantly as the seed spacing distance was narrowed, however, the largest yield increases occurred between the 9- and the 6-inch spacing. Apparently this seed spacing effect was not uniform for all varieties since, as stated previously, the interaction Seed Spacing x Variety was significant for all data (yield, average tuber weight, and number of tubers per hill). Accordingly these data have been analyzed further to examine the effects of the Seed Spacing x Variety interaction and the results obtained are presented separately.

Interaction: Seed Spacing x Variety

Yields

The average yields per acre (2-inch minimum-grade) for the two variables, Seed spacing and Variety, are shown in table 3. Appropriate values are also supplied for testing the significance of the yield differences obtained. Although Merrimack produced consistent yield increases when its seed spacing was narrowed from 12 to 6 inches, none of these increases was significant. On the other hand, all similar reductions in seed-spacing with Saco produced highly significant yield increases. Kennebec and Katahdin varieties planted with seed spaced 6 inches apart also produced significantly higher yields than when spaced 9 inches apart. In general, all 4 varieties gave the highest yields with 6-inch-spaced seed. However, with one exception, the highest yield for Merrimack was lower than the lowest yield listed for the 3 other varieties, regardless of seed spacing. On the

TABLE 2.—*Main effects. Average yields — 2-inch minimum grade.*

Fertilizer	1000 lb.	1200 lb.	1400 lb.	1600 lb.
Yield (Cwt./A.)	299.8	322.8	351.6	351.7

L.S.D., .05 level = 8.5 cwt., .01 level = 12.2 cwt.

Varieties	Saco	Kennebec	Katahdin	Merrimack
Yield (Cwt./A.)	387.5	354.2	308.2	276.0

L.S.D., .05 level = 10.1 cwt., .01 level = 13.6 cwt.

Seed Spacings	6-inch	9-inch	12-inch
Yield (Cwt./A.)	355.8	326.3	312.4

L.S.D., .05 level = 7.8 cwt., .01 level = 10.3 cwt.

TABLE 3.—*Interaction: seed spacing x variety — yields per acre.*

	Average Yields (2-inch minimum grade) at spacing shown		
Variety	6-inch	9-inch	12-inch
	Cwt.	Cwt.	Cwt.
Saco	420.1	383.5	358.8
Kennebec	374.9	348.1	339.6
Katahdin	338.2	298.8	287.7
Merrimack	289.8	274.8	263.5

Spacing L.S.D. .05 level = 15.5 cwt., .01 level = 20.5 cwt.
Variety L.S.D. .05 level = 17.5 cwt., .01 level = 23.4 cwt.

basis of their yielding ability at the 6-inch seed spacing, the varieties Saco, Kennebec, and Katahdin appear to be much better adapted for intensive production than is Merrimack.

Weight of Tuber

Data for the average weight of tuber produced by each of the 4 varieties with seed spaced 6, 9, and 12 inches apart are shown in the upper part of table 4. The tubers of all varieties tended to decrease in weight as the seed was spaced closer, however, this effect was not uniform for all varieties. Kennebec, for example, showed the greatest reduction

TABLE 4.—*Interaction: spacing x variety—average tuber weight and number of tubers per hill (2-inch minimum grade).*

Tuber Size, Number per Hill, and Variety	Seed Spacing		
	6-inch	9-inch	12-inch
Weight per Tuber:[1]	Ounces	Ounces	Ounces
Saco	5.92	6.29	6.86
Katahdin	6.95	7.84	8.62
Kennebec	5.20	5.71	5.77
Merrimack	4.74	5.09	5.64
Tubers per Hill:[2]	Number	Number	Number
Saco	3.69	4.76	5.47
Katahdin	2.81	3.47	4.11
Kennebec	3.39	4.13	5.21
Merrimack	3.19	4.22	4.87

	Spacing	Varieties
[1]L.S.D. .05 level	0.168 oz.	0.182 oz.
L.S.D. .01 level	0.225	0.241
[2]L.S.D. .05 level	0.948 oz.	1.631 oz.
L.S.D. .01 level	1.255	2.189

in tuber weight when the seed was planted 6 inches apart, although the average tuber weight for Kennebec was, without exception, the highest among the varieties tested. Its tubers averaged more than 2 ounces heavier than those of Merrimack at 6-inch spacing. At every seed spacing the average weights of Saco and Kennebec tubers were significantly heavier than those of Katahdin and Merrimack. These results indicate that Saco and Kennebec apparently can be considered among varieties requiring close seed spacing to avoid production of over-sized tubers. From this standpoint, Katahdin occupied an intermediate position between Merrimack and the two varieties Saco and Kennebec.

Tubers per Hill

Also included in table 4 (lower part) are data showing the average number of tubers per hill produced by the 4 varieties when planted at 3 spacing distances. Narrowing the seed spacing had a general tendency to reduce the average number of tubers per hill. However, this effect was not uniform nor were the reductions in number of tubers per hill usually significant, except for the 12- and 6-inch comparisons, which were all highly significant. Kennebec produced the smallest number of tubers per hill at each seed spacing, while Saco produced the largest number. In view of the high yields from these two varieties and the fact that number of tubers per hill and their size are two functions of yield, it seems appropriate to examine the data in table 4 to obtain an explanation for these apparently

anomalous relationships. It will be found, for example, that Kennebec at 6-inch spacing produced 2.81 tubers per hill, which averaged 6.95 ounces, whereas similar values for Saco were 3.69 and 5.92. This differential relationship between number and weight of tubers which occurred at all spacings would account in part for the high yields of these two varieties.

A further explanation can be found in the differences in number of plants per plot at the different seed spacings. In the present experiment there were, for example, twice as many plants at the 6-inch spacing as at the 12-inch and one-third more at the 9-inch, than at the 12-inch. Increases in yields obtained from greater plant density as spacing was narrowed, as shown in table 3, apparently more than compensated for any reductions that resulted therefrom in tuber size and number per hill.

The whole problem concerning the relationship between plant density and yield, however, is complicated by factors such as leaf shading which tends to limit production at high plant densities. Watson (1) found that there usually was a negative correlation between high plant density and production of crops like potatoes. However, the data in table 3 indicate that potato varieties differ in their reactions to intensive growth conditions. Whether these varietal differences are caused simply by differences in types of vine growth, or by differences in chlorophyll efficiency that may exist in certain potato varieties, may provide a field for further investigation.

Financial Returns

Two of the factors used in the present experiment, seed spacing and fertilizer rate, involve differences in the cost of production. To complete the study, therefore, we must consider the financial returns from these expenditures. Even though most of the yield comparisons previously discussed were statistically significant, this does not necessarily convey assurance that they were also economically significant.

The financial returns per acre, representing gross returns minus the cost of seed and fertilizer in each case, have been calculated for all the variables and the results are presented in table 5.

The ranges in financial returns from each of the 4 varieties can be compared to assess their relative responses to intensive production methods. In the order of their magnitude they are Saco $438 to $570; Kennebec $368 to $490; Katahdin $327 to $437; and Merrimack $270 to $352. Applications of fertilizer up to 1,400 pounds per acre generally increased the financial returns from all varieties, but in 7 out of 12 cases when the rate was increased to 1,600 pounds, the financial returns were reduced. The results obtained from Saco, Kennebec, and Katahdin show that the limit of economical production had been reached under the prevailing conditions, when a combination of 1,400 pounds of fertilizer per acre and 6-inch seed spacing was used. Compared with the financial returns from Katahdin, those from Merrimack were consistently lower, whereas those from Saco and Kennebec were consistently higher. These financial relationships and similar comparisons for yields, previously discussed, provide information on the responses of the 4 varieties that should prove helpful in the selection of a variety for intensive production purposes.

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1. Watson, D. J. 1956. Leaf growth in relation to crop yield. Proc. 3rd Easter School in Agr. Sci. Univ. of Nottingham.

TABLE 5.—*Net financial returns per acre[1] from 4 potato varieties fertilized and spaced differently.*

Spacing and Fertilizer Rate per Acre	Returns per Acre from Variety Indicated			
	Saco	Kennebec	Katahdin	Merrimack
	Dollars	Dollars	Dollars	Dollars
6-inch Spacing:				
1000 Pounds	486	416	351	282
1200 Pounds	507	424	379	300
1400 Pounds	570	475	437	352
1600 Pounds	526	490	408	338
Average	522	451	394	318
9-inch Spacing:				
1000 Pounds	453	368	327	291
1200 Pounds	477	438	356	332
1400 Pounds	526	487	364	327
1600 Pounds	515	456	393	340
Average	493	437	360	323
12-inch Spacing:				
1000 Pounds	453	401	327	270
1200 Pounds	438	433	347	334
1400 Pounds	478	477	375	341
1600 Pounds	503	441	378	330
Average	468	438	357	319

[1]Gross returns minus the cost of seed and fertilizer. Seed was estimated at $2.50 per cwt; 10-15-15 fertilizer at $80.00 per ton; and tablestock at $1.57 per cwt.

In this particular experiment the financial returns above the cost of seed and fertilizer may be higher than usual because of the high yields obtained during a favorable season. In all experiments of this type the results of more than one season are always required before any generalizations can be considered. Fluctuations in the cost of seed and fertilizer, and differences in the price received for table stock from year to year, will also affect the financial returns. Such fluctuations, if given due consideration, in no way affect the soundness of the principles involved in the procedure.

THE EFFECT OF SIZE AND SPACING OF SEED PIECES ON THE YIELD AND GRADE OF WHITE ROSE POTATOES IN KERN COUNTY, CALIFORNIA.[1]

J. C. Bishop and D. N. Wright[2]

Introduction and Literature Review

Stuart *et al.* (6), who made an extensive review of the literature prior to 1920, reported on seed piece studies made as early as 1776. From this and later papers, by Bates (1), Chucka *et al.* (2), Singh and Wakankar (3), Smith *et al.* (4), Starring (5), Wakankar (8), and Terman *et al.* (7), it is evident that the influence of size and spacing of seed pieces is modified by such factors as climate, fertility, and variety. However, in the majority of cases reported, the fact stands out that both larger seed pieces and closer spacing usually produce higher yields of smaller tubers, with spacing often producing this effect to a greater degree.

Potato growers in the south of California's San Joaquin Valley generally plant about twenty 100-pound sacks of seed potatoes per acre. These seed tubers are usually cut into fairly small pieces (many weighing one ounce or less), which are planted at 6 to 8-inch intervals in rows 30 to 32 inches apart. White Rose is the principal variety. Planting of the spring crop extends from early December to early March, with the bulk of the acreage being planted during January and February. Harvesting begins in mid-April and extends to early July. Market shipments are heaviest from about May 10 to about June 25.

Materials and Methods

These experiments were conducted over four years (1952-1955) on Hesperia sandy loam soil at the U. S. Cotton Field Station, Shafter, California. Certified White Rose seed potatoes were cut into 1-ounce, 1½-ounce, and 2-ounce pieces. Each seed piece was individually weighed, except in 1952, when the seed tubers were cut into unweighed pieces of about 1 and 2 ounces, as judged by the cutters from weighed samples placed before them. Two spacing intervals were used—15 and 7½ inches. The seed pieces were planted with a conventional assisted-feed potato planter, which placed the seed pieces 6 to 7 inchs deep and spread fertilizer in two bands about 2 inches below and 2 inches to each side of the seed pieces. Fertilization rate was slightly above a level determined to be adequate in fertilizer trials. The customary irrigation schedule used in the area was followed. Each year the plots were planted in early February and harvested in early June. Individual plots were single rows (2 rows in 1952), 32 inches

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apart; they varied from 45 to 125 feet long in different years. Each treatment was replicated four times, in a randomized block design, in 1952 and 1953 and six times in 1954 and 1955. Following harvest by a conventional mechanical digger and hand picking, the entire yield per plot was graded. In 1952, random samples of 35 to 50 pounds were taken from each plot for grading. Tubers were initially divided into two classes: (1) "rough", which included misshapen, growth-cracked, and second-growth tubers, and (2) "smooth", the well-shaped tubers. Injuries caused by disease, insects, or handling were not considered in the grading. The smooth tubers were further divided by means of sizing rings into three groups: (1) under 1⅞ inches in diameter,(2) 1⅞ to 2¼ inches in diameter ,and (3) more than 2¼ inches in diameter. The sum of the last two classes closely represent U. S. No. 1 grade yields. Many of the 2¼-inch tubers averaged about 6 ounces each.

Results and Discussion

Both larger seed pieces and closer spacing increased total yield (Table 1.). Where the same quantity of seed potatoes were planted per acre (16⅓ sacks) there was little difference in yield from 1-ounce seed pieces spaced 7½ inches apart and 2-ounce pieces spaced 15 inches apart. The second method gave but slightly greater yields.

The use of larger seed pieces and closer spacing also increased the yield of smooth tubers over 1⅞ inches in diameter, U. S. No. 1 yield (Table 2). These increases, however, were somewhat smaller than increases in total yield, and were more erratic from year to year. The larger seed pieces raised U. S. No. 1 yield more when spaced at 15 inches than when spaced at 7½ inches. Close spacing of small seed pieces was more effective in raising U. S. No. 1 yield than close spacing with large pieces.

At the 15-inch spacing, the percentage of U. S. No. 1 tubers was not affected by seed piece size as shown in table 3. At the 7½-inch spacing there was a small decrease in percentage of U. S. No. 1's as seed piece size was increased. With 1-ounce seed pieces, spacing had little or no effect on the percentage of U. S. No. 1's; with larger seed pieces, wider spacing gave a higher per cent of U. S. No. 1's.

It is economically significant to compare the yield of U. S. No. 1 tubers with the quantity of seed potatoes needed to plant an acre. Average figures indicate a continuous increase in yield as the quantity of seed potatoes is increased, but at a declining rate. Increasing the quantity of seed potatoes from 8⅙ sacks to 16⅓ sacks per acre increased U. S. No. 1 yield at approximately 8 to 49 sacks per acre, averaging 30 sacks. Increasing the quantity of seed potatoes further—to 32⅔ sacks—increased the average yield of U. S. No. 1 potatoes by approximately 10 sacks. With equal quantities of seed tubers (16⅓ sacks per acre), 2-ounce seed pieces 15 inches apart produced only slightly more U. S. No. 1 potatoes than did 1-ounce pieces 7½ inches apart. With plantings up to 16⅓ sacks of seed per acre the percentage of total yield in the U. S. No. 1 classification averaged 85 or 87 per cent; increasing the seed rate to 32⅔ sacks per acre, resulted in reducing the percentage of U. S. No. 1's 5 or 6 per cent.

TABLE 1.—*Total yield of White Rose potatoes with varied seed piece size and spacing.*

Seed Piece		Seed Potatoes	Total Yield (100-Lb. Sacks per Acre)					
Size (Oz.)	Spacing in Row (Inches)	Required (100-lb. Sacks/A)	1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	247	296	328	262	283	295
1	7½	16⅓	276	346	340	289	312	325
1½	15	12¼	..	327	305	290	..	307
1½	7½	24½	..	355	353	304	..	337
2	15	16⅓	294	337	350	307	322	331
2	7½	32⅔	331	369	371	336	351	359

Difference required for significance at odds of 19:1 — 1952: 17; 1953: 26; 1954: n.s.; 1955: 19

TABLE 2.—*Effect of seed piece size and spacing on yield of smooth, well-shaped tubers over 1⅞ inches in diameter (U.S. No. 1)*

Seed Piece		Seed Potatoes	U.S. No. 1 Yield (100-Lb. Sacks per Acre)					
Size (Oz.)	Spacing in Row (Inches)	Required (100-lb. Sacks/A)	1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	226	256	270	227	245	251
1	7½	16⅓	248	314	269	252	270	278
1½	15	12¼	..	293	240	254	..	262
1½	7½	24½	..	311	273	259	..	281
2	15	16⅓	254	296	288	273	278	286
2	7½	32⅔	280	315	266	274	284	285

Difference required for significance at odds of 19:1 — 1952: 24; 1953: 33; 1954: n.s.; 1955: 23

TABLE 3.—*Effect of seed piece size and spacing on percentage of smooth, well-shaped tubers over 1⅞ inches in diameter (U.S. No. 1).*

Seed Piece		Seed Potatoes	Per cent of Total Yield					
Size (Oz.)	Spacing in Row (Inches)	Required (100-lb. Sacks/A)	1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	91.6	86.6	82.5	86.6	87.0	85.3
1	7½	16⅓	89.9	90.9	79.0	87.1	87.0	86.0
1½	15	12¼	..	90.0	79.3	87.7	..	86.0
1½	7½	24½	..	87.5	77.3	85.2	..	83.6
2	15	16⅓	87.2	88.0	82.2	89.2	86.8	86.6
2	7½	32⅔	85.2	85.5	71.5	81.5	81.2	79.8

Difference required for significance at odds of 19:1 — 1952: n.s.; 1953: n.s.; 1954: 0.4; 1955: n.s.

The portion of the U. S. No. 1 yield over 2¼ inches in diameter, as shown in tables 4 and 5, was affected by both the size and spacing of the seed pieces. The 15-inch spacing yielded more of these large tubers than did the 7-½ inch spacing. At the wider spacing, 65 to 90 per cent of the U. S. No.1 yield fell into this larger size. At the 7½-inch spacing the figure was about 17 or 18 per cent less. Although increasing the size of the seed pieces decreased the proportion of large tubers, the effects of seed-piece size were less significant than the effects of spacing.

The yield of U. S. No. 1 tubers under 2¼ inches in diameter (Table 6) was increased by closer spacing and by larger seed piece size.

The yield of smooth tubers under 1⅞ inches in diameter (Table 7), about 10 per cent of the total crop, was increased by planting the larger seed pieces at the closer spacing. Again, spacing had a greater effect than did seed piece size.

The yield of 'rough" tubers which generally did not exceed 10 per cent of the total yield, was not significantly affected by either size or spacing of seed pieces and no consistent trends were apparent (Table 8).

Summary

Both total yield and, to a somewhat lesser degree, yield of U. S. No. 1 tubers were increased by increasing the quantity of seed potatoes planted per acre—through closer spacing and/or larger seed pieces. The rate of yield increase declined with each increment of seed potatoes. Planting more than approximately 16 sacks of seed potatoes per acre did not increase the yield sufficiently to justify the greater expense.

Large seed pieces spaced at 7½-inch intervals produced the highest proportion of small tubers. Potato size was determined more by spacing than by seed piece size.

The yield of "rough" tubers (misshapen, growth-cracked, and second-growth tubers) was slightly and inconsistently affected by size or spacing of seed pieces.

Table 4.—*Effect of seed piece size and spacing on yield of smooth, well-shaped tubers over 2¼ inches in diameter.*

Seed Piece		Seed Potatoes Required (100-lb. Sacks/A)	Yield (100-Lb. Sacks per Acre)					
Size (Oz.)	Spacing in Row (Inches)		1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	183	239	196	183	200	206
1	7½	16⅓	157	267	129	155	177	184
1½	15	12¼	..	266	159	188	..	204
1½	7½	24½	..	260	112	138	..	170
2	15	16⅓	220	266	171	190	212	209
2	7½	32⅔	191	254	95	135	169	161
Difference required for significance at odds of 19:1			31	n.s.	41	22		

TABLE 5.—*Effect of seed piece size and spacing on yield of smooth, well-shaped tubers over 2¼ inches in diameter as per cent of U.S. No. 1 yield.*

Seed Piece		Seed Potatoes	Per cent of U.S. No. 1 Yield over 2¼ Inches in Diameter					
Size (Oz.)	Spacing in Row (Inches)	Required (100-lb. Sacks/A)	1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	81.2	93.5	71.9	80.6	82.6	83.1
1	7½	16⅓	63.0	85.1	47.7	61.2	65.0	65.7
1½	15	12¼	..	90.8	65.8	73.7	..	77.8
1½	7½	24½	..	83.6	40.7	53.5	..	60.2
2	15	16⅓	86.6	90.0	58.9	69.5	77.5	74.1
2	7½	32⅔	68.9	80.5	35.4	49.7	59.2	55.9
Difference required for significance at odds of 19:1			1.1	0.5	0.6	0.5		

TABLE 6.—*Effect of seed piece size and spacing on yield of smooth, well-shaped tubers between 1⅞ and 2¼ inches in diameter.*

Seed Piece		Seed Potatoes	Yield (100-Lb. Sacks per Acre)					
Size (Oz.)	Spacing in Row (Inches)	Required (100-lb. Sacks/A)	1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	43	17	74	44	45	45
1	7½	16⅓	91	46	139	97	93	94
1½	15	12¼	..	27	81	66	..	58
1½	7½	24½	..	51	162	121	..	111
2	15	16⅓	34	29	117	83	66	77
2	7½	32⅔	89	61	171	139	115	124
Difference required for significance at odds of 19:1			28	13	25	23		

TABLE 7.—*Effect of seed piece size and spacing on yield of smooth, well-shaped tubers 1⅞ inches or less in diameter.*

Seed Piece		Seed Potatoes	Yield (100-Lb. Sacks per Acre)					
Size (Oz.)	Spacing in Row (Inches)	Required (100-lb. Sacks/A)	1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	7	5	25	12	12	14
1	7½	16⅓	17	10	44	23	24	26
1½	15	12¼	..	7	27	15	..	16
1½	7½	24½	..	14	52	33	..	33
2	15	16⅓	9	6	30	17	15	17
2	7½	32⅔	23	16	65	38	35	40
Difference required for significance at odds of 19:1			9	4	12	6		

TABLE 8.—*Effect of seed piece size and spacing on yield of rough tubers (misshapen, growth-cracked, and second-growth).*

Seed Piece		Seed Potatoes	Yield (100-Lb. Sacks per Acre)					
Size (Oz.)	Spacing in Row (Inches)	Required (100-lb. Sacks/A)	1952	1953	1954	1955	Average 4 Years 1952-55	Average 3 Years 1953-55
1	15	8⅙	14	34	33	23	26	30
1	7½	16⅓	11	22	27	14	18	21
1½	15	12¼	--	27	38	21	--	29
1½	7½	24½	--	30	28	12	--	23
2	15	16⅓	31	35	32	17	29	28
2	7½	32⅔	28	38	40	24	32	34
Difference required for significance at odds of 19:1			n.s.	n.s.	n.s.	n.s.		

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EFFECT OF PROCESSING VARIABLES ON POTATO GRANULE PRODUCTION[1]

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Potato granules are dehydrated mashed potatoes in powder or granule form that can be quickly reconstituted to mashed potatoes by the addition of hot liquid.

Production in the United States is by the "add-back" process, in which previously dried granules are mixed with fresh cooked potatoes to yield a friable "moist-mix" that can be readily dried to a granular product. The process is outlined schematically in figure 1. Quality specifications for the product are constantly being raised in regard to color, flavor, and texture. A product that can be reconstituted by addition of boiling or near boiling liquid to give a natural white mashed potato of pleasant flavor and mealy texture is the current goal of industry. To maintain such quality requirements, it is necessary to study each step to learn how to adjust procedures related to quality.

Several reports on the manufacturing process have been published. Olson and Harrington (9) published a review in 1951 of methods of production and of advantages of granules as compared with other forms of dehydrated potato (dice, julienne, strips, and riced). Olson *et al.* (10) discussed such factors as moisture content of the moist granular mixture, equilibration time, drying temperatures in connection with product quality, and release of "free starch" by mechanical damage of tissue cells.

Neel *et al.* (8) discussed two driers used in potato granule production: the air-lift and fluidized-bed driers. Other developments were reported by Cooley *et al* (2) and by Olson and Harrington (11, 12).

Many inquiries have been received concerning details of the add-back process. These questions are related to unusual steps in the add-back process and their contribution to quality. Some steps exert overlapping effects. This publication presents laboratory findings on the effects of variations in several processing steps on quality of product.

METHODS

Processing Procedure. A standard procedure was evolved for use as a control, when required. In this procedure, hot, cooked, peeled potatoes, direct from the cooker, were immediately mash-mixed with the add-back granules, in the covered 5-quart bowl of a Kitchen Aid[3] planetary mixer with a paddle spade, operating at low speed. Sulfite solution was added at the beginning of the 5-minute mixing period. The desired temperature at end of mash mixing was 140° F. and the moisture content was 37 to 39 per cent. Following mash-mixing, the moist mixture was cooled on trays for 10 minutes or in a fluidized bed cooler for 5 minutes. During this time the temperature dropped to 60° or 70° F. The cooled mixture was

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put back into the mixing bowl, mixed 5 minutes at low speed, and then allowed to stand (temper) for one hour. The final mixing period was 5 minutes. The moist mixture was dried in an air-lift drier as described by Olson *et al.* (10). Air temperature of two drying passes was 210° to 220° F. Final finish drying was in a fluidized bed drier with an inlet air temperature of 140° F. The product was removed when its temperature reached 100° F. with the moisture content about 8 per cent. The dried product was screened. Usually one cycle was completed per day, but with several experiments concurrently carried out.

The process is complicated by the necessity of recycling to a steady-state condition to eliminate the effect of the original add-back material. Poor-quality add-back granules may mask small changes caused by variables. In this study, repeated samples were taken between successive cycles of a repeated set of conditions to evaluate the effects of a particular change in process. Recycling was continued until no further change was observed in quality of product. After a steady state was reached, the product was compared with those of other runs to determine the effect of the particular variable being studied.

Evaluation of Potato Granules

Particle Size. Sieve-size classification of the dried product was made by passing the materials over U. S. standard sieves which were shaken for 5 minutes on a Cenco-Meinzer shaker at intermediate speed. The fraction of product separated by each sieve size is reported as percentage of the entire product yield. The coarse fraction held on a No. 16 sieve was discarded. The minus 60 or 70 mesh size was used as the finished product. The intermediate sizes 16 to 40 and 40 to 70, were used as add-back material for the next cycle, augmented with enough finer material to obtain the amount required. Information on size classification was very useful in estimating the effectiveness of the process in separating individual potato tissue cells.

Moisture Content. The determination of moisture was made by toluene distillation (1). Ten grams of moist or dry sample was distilled with toluene for 25 minutes.

Estimation of Free Starch in Potato Granules. Blue Value Index was determined by the method of Mullins *et al.* (6). This method was varied slightly in its use on the moist-mixtures of add-back granules and freshly cooked potatoes to keep the same solids-water ratio as used when analyzing the dry product.

The Drop Test for Consistency. The method of Mullins *et al.* (7) was used to measure differences between samples after reconstitution.

Color Measurement. The color of potato granules was usually measured by comparison to a standard color plate (Ivory No. 31; Rd, 57.0; a, —1.6; b, +24.6) with the Hunter Color and Color-Difference Meter. This instrument appeared nearly as sensitive as the eye in detecting reflected color changes. The minus 70 sieve size potato granules gave very uniform packing at ¾-inch depth in the sample holders.

Extracted color was used to evaluate color changes in some of the experiments requiring color measurements. In this method, a modification of that of Hendel *et al.* (5), the color from 5 grams (moisture-free basis) of potato granules was extracted by 100 ml. of 55 per cent (v/v) ethyl

alcohol. The granules were shaken with the alcohol mixture for 2 hours, then filtered through Whatman No. 3 filter paper before reading in a 5 cm. cell at 390 millimicrons in a Beckman DU Spectrophotometer. The results are reported as optical density values.

Organoleptic Panel Appraisal of the Reconstituted Product. The general method used was that described by Wood *et al.* (17). For the investigation of this report, the standard appraisal method was varied by use of hot water at a temperature of 180 $\pm 5°$ F. in reconstituting the granules in order to detect smaller differences between samples than was possible by the cited method, in which 160° F. water was used.

Subjective panel appraisals were not used for evaluating the product between cycles, but only on samples taken at the completion of individual runs.

Results and Discussion

The discussion of experimental results is arranged to follow as closely as possible the process segments or steps outlined in figure 1. The effects of alteration in the process are generally discussed in relation to the standard procedure, but this was not always possible.

Peeling. The completeness of peeling and trimming necessary in granule manufacture is somewhat dependent upon the process used. For example, if ricing is used in place of mash-mixing, the peel and blemish fragments from the unpeeled cooked potatoes may block the ricer holes and damage the mash. In most other mashing methods (mash-mixing, roller, and hand), the skin and blemish fragments did not interfere but tended to remain intact in relatively large particles which can be removed by screening the moist-mixture or the final dry material. Of course, the completeness of peeling affects process costs by the losses caused by peeling as well as the extra labor for trimming.

Table 1 presents data comparing some of the effects of using washed, unpeeled and hand peeled Russet Burbank potatoes for laboratory granule production. The comparison is between peeled and unpeeled potatoes weighed just before cooking. It does not include a prior 17 per cent hand-peeling loss. This peeling loss would decrease the granule yield still more (2 to 3 per cent on the dry-weight basis) for the peeled potatoes if based on the weight of the original tuber stock.

During cooking there was less sloughing and surface hydration in the unpeeled potatoes. The unpeeled potatoes gave a higher yield of product. Other similar experiments gave 2 per cent increased yield for the unpeeled, compared with the peeled potatoes. The color of the product from unpeeled potatoes was darker. This is shown by the color extracted from the finished product. Light, white-skinned potatoes did not contribute as much color to the product as the darker russeted varieties. On panel appraisal, the flavor of granules from unpeeled potatoes was reported as earthy or baked Other quality factors such as product density and texture did not appear to be affected by the peel.

Cooking. Cooking time was found to be of great importance. It was observed that the firmer pieces from inadequate cooking left bits of unmashed potato in the moist-mixture when mash-mixed. These pieces, if not screened out before drying, dried into hard, rice-like material. This

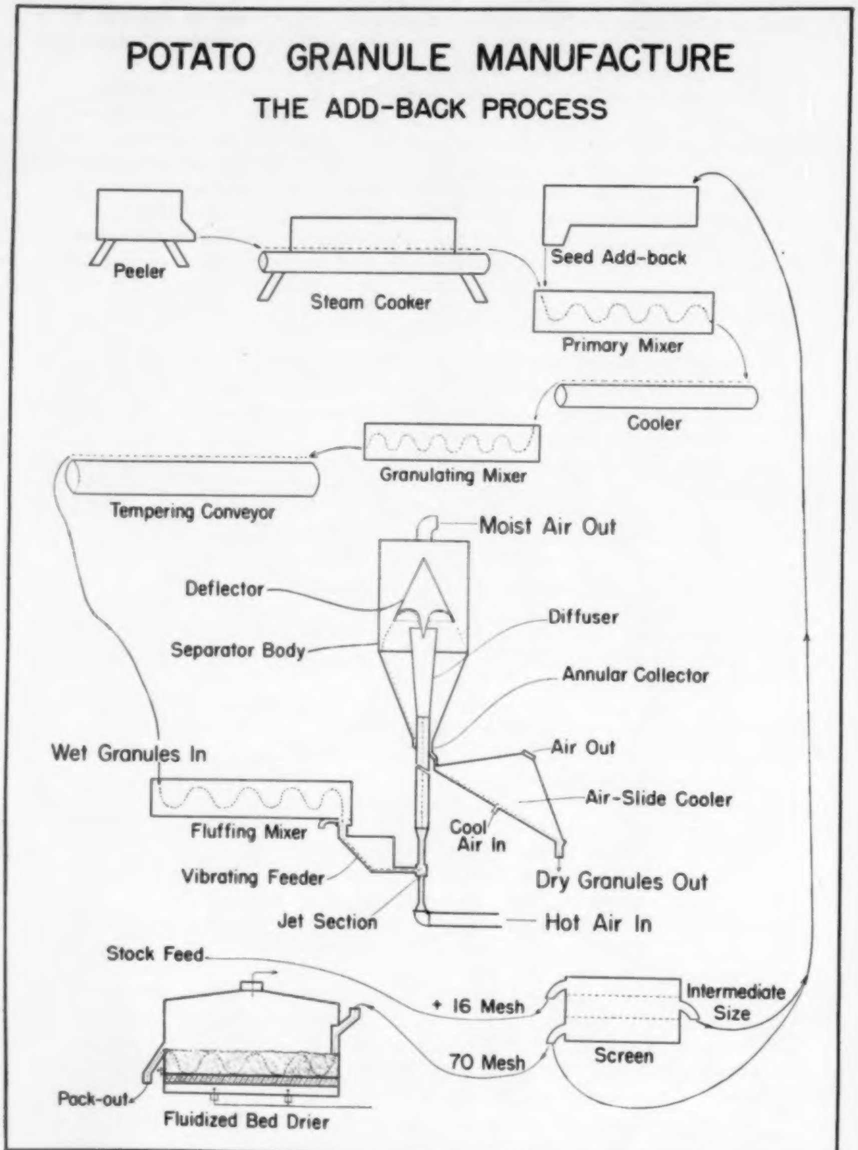

FIGURE 1.—Schematic design of "add-back" process used in manufacture of potato granules.

TABLE 1.—*Potato granules from peeled and un-peeled potatoes.*

	Yield Weight	Density Gm/cc	Extracted Color[1]	Blue Value Index	Drop Test Cake Diameter
	Per cent				mm.
Hand Peeled	17	0.87	0.555	80	60
Unpeeled	20	0.87	0.744	88	60

[1]Optical density of extract. See text.

degraded the product and its use as add-back material, because the hard coarser material does not readily absorb moisture or soften during mixing in the next cycle. Overcooking caused sloughing or excessive tissue softening and increased the damage caused by mashing. Doneness was estimated by observing the ease with which the cooked potato could be separated by a table fork. No objective method was found to indicate doneness.

Either boiling water or atmospheric steam cooking was used. Pressure cooking used in some trials resulted in lower product quality. Piece size was varied from ⅜-inch dice to whole potato. In the control and in most other experiments, the potatoes were cut into pieces about ¾-inch thick to obtain rapid and uniform cooking. The cooking requirement for each lot of potatoes was checked. Usually 25 ±5 minutes of steam cooking was required for the ¾-inch pieces. Three-eighths-inch potato dice were cooked in less time. If the dice were inadequately washed before cooking, a glaze of gelatinized starch was observed on the cooked dice. This gave an inferior product compared with samples from diced potatoes washed in 3 times their weight of water agitated by compressed air. Increased yellowness and off-flavor were observed when cooked potatoes were kept hot in a covered container. This was more noticeable in the early spring with stored potatoes that were beginning to sprout.

Mashing and Mixing. It was found that mashing must be carefully controlled. In this step, the cooked potato (at approximately 78 per cent moisture content) was separated into small aggregates or cellular units with a minimum of cell breakage. Cell damage from over-mashing reduced quality by increasing stickiness due to "freed" starch. Under-mashing left bits of unseparated fresh potato to dry into hard particles. Mashing was done by hand, on rolls, by ricing, in mechanical mixers, and by mash-mixing (mashing and mixing with add-back granules in one operation). The data are recorded in table 2. Mash-mixing in small scale planetary type equipment appeared the most suitable. It accomplished gentle mashing and mixing with the add-back granules. Mixing is necessary in all methods.

Lower Blue Value Index values in table 2 indicate less product damage in the mash-mixed runs. The temperature of the moist material prepared by mash-mixing was about 20° F. higher than that of mixtures in which the cooked potato was mashed before adding the add-back granules. This was important in reducing mixing damage as will be discussed more fully below. In subsequent studies, it was observed that a better product was produced in experimental runs in which all the add-back granules

were added at the start of mashing if the moisture content of the moist-mixture was above 35 per cent.

With slow mixing, the fresh hot potato without add-back very quickly produced a sticky mash. Mechanical mixing of dry add-back granules was also very damaging. Table 3 shows the effect of mechanical damage to both moist and dry granules when subjected to constant damage, by passage through a duct system and a fan for 1, 3, and 5 times. The rate of increase in Blue Value Index in the dry granules per cycle was almost three times that in the moist-mixture. Data from other experiments revealed that mixtures containing 43 per cent moisture were less damaged during passage through the fan than mixtures containing 28 per cent moisture. A mixture of 42 per cent moisture was less damaged after three hours of tempering (holding) than after one hour, but in a mixture of 33 per cent moisture the resistance to damage was not increased by increasing tempering from one to three hours. These effects will be discussed more fully below in connection with the tempering operation.

To determine the effect of mash-mixing at low speed in the planetary mixer, moist samples were taken after different mixing intervals. Blue Value Index was determined immediately after sampling, since a delay in analysis was found to reduce the Blue Value. The effect of mixing time is shown in table 4. The data recorded show the average results of three separate experiments using White Rose potatoes. The mixer was run at low speed, uncovered, and cooled by blowing air over it with an electric fan. Two and a half minutes of mixing was apparently the shortest interval for adequate mashing and mixing of the fresh potato and the add-back granules to provide a reasonably homogeneous mixture. If mixed longer than two and a half minutes, only a moderate increase in the Blue Value Index resulted.

The importance of mixing temperature is shown in table 5. Russet Burbank potatoes were used in this set of experiments. Maintaining a higher temperature of mash-mixing by covering the mixer avoided damage that occurred when the temperature fell to 70° F. before the mashing was complete. Prolonged mixing after the initial period did not appreciably damage the mixture.

Similar trends were observed in other experiments in which the mixture was mixed for as long as six hours. Discoloration and off-flavor developed in some moist mixtures when held three to four hours above 140° F., whereas others became sticky when held above this temperature.

The benefit of room temperature mixing was found to result in an increased yield of finely separated, high density potato granules.

Rapid cooling before completely mashing the fresh potato was very damaging. Such cooling was experimentally done by blowing carbon dioxide gas from dry ice through the mixer after one minute of mash-mixing, and cooling the mixture to approximately 35° F. in the next 5 minutes. This damage was reduced if mash-mixing was continued for five minutes before the start of the cooling period.

From these and other experiments, the standard mash-mixing procedure was developed. In this procedure, hot cooked potato, directly from steam racks was placed in the mixer with the add-back granules, covered, and mash-mixed five minutes. The temperature at the end of mash-

TABLE 2.—*Effect of mashing methods on potato granules.*

Mashing Method	Blue Value Index	Product Density g./cc.
Hand Mashing[1]	112	0.91
Mechanical Mashing[1]	109	0.90
Mash-Mixing[2]	63	0.89
Mash-Mixing[3]	71	0.89

[1]Mixed with add-back granules after mashing.
[2]All add-back granules added at beginning of mashing.
[3]Add-back granules added in two stages.

TABLE 3.—*Effect of mechanical damage to moist and dry granules.*

Product through Fan	Increase in Blue Value Units	
	Dry[1]	Moist[2]
1 cycle	6	2
3 cycle	33	11
5 cycle	86	35

[1]8 per cent moisture.
[2]38 per cent moisture.

TABLE 4.—*Effect of mixing time.*

Mixing Time Minutes	Temperature °F.	Blue Value Index Moist Mixture
0	(ca) 150	..
2½	110	185
5	90	190
10	75	200
15	73	204
	Tempering period–3½ hours at room temperature[1]	
30	70	207
45	70	211

[1]Following the first 15 minutes of mixing, the moist mix was tempered for 3½ hours before the final 30 minutes of mixing.

TABLE 5.—*Effect of mixing temperature and of continuous mixing.*

Mixing Time Min.	Covered Mixer		Open Mixer	
	Temperature of Mixture, °F.	Blue Value Index[1]	Temperature of Mixture, °F.	Blue Value Index[1]
15	138	114	75	164
30	136	103	78	170
60	132	104	69	183
120	125	100	72	189
180	115	90	78	176

		Covered Mixer	Open Mixer
Product Yield by Sieve Size		Per cent	Per cent
	—70	64	96
	+70	36	4
Density, g./cc.		0.89	0.96

[1]Blue Value Index by revised method for moist-mixture (38 per cent moistened).

mixing was about 140° F. This appeared to give rapid mashing of the fresh potato, rapid softening of the add-back granules, and rapid moisture equilibration throughout the mixture. The temperature at the end of mixing was at the lower limit for noticeable heat damage and tackiness in the mixture.

Cooling and Granulating. After completion of the hot mash-mixing and moisture equilibration (5 minutes at 140° F.), the mixture was not completely friable but retained some stickiness. This caused the moist mixture to form clumps, or to agglomerate, during standing. The stickiness was rapidly reduced by cooling to room temperature or lower. Cooling the friable mixture was slow unless air was blown through or over it. Very rapid cooling was obtained in experimental production by blowing room temperature air through the moist-mixture after mash-mixing. This was done by placing it on a porous plate and blowing air up through the plate and product. The equipment used was a small fluidized bed dryer, but at the moisture content of the friable mixture fluidization did not occur. Cooling was accomplished in three to five minutes, depending upon the volume of air used.

The agglomerated clumps of cells formed by initial stickiness in the moist-mixture remained as such if they were not separated immediately after cooling. Stirring or slow mixing during cooling resulted in reduced coarseness in the final product.

Since the changes in stickiness were not instantaneous, a second or granulating mixing (five minutes) was very beneficial in increasing the yield of fine (minus 70 sieve size) high density potato granules. If the granulating mix was delayed, permitting the agglomerates to become more firmly stuck together, then either they were not broken apart by mixing, or greater cell damage occurred when they were finally separated. In both instances an inferior product resulted. At this point, the cells had not,

as yet, become sufficiently firm to be resistant to increased mixer damage.

Tempering. The tempering (holding the moist-mixture at room temperature) normally began ten to fifteen minutes after mash-mixing. During cooling and granulating much of the initial stickiness was reduced. Tempering further improved granule quality. The tendency to re-agglomerate was reduced and the material became more resistant to mixer damage and more friable, and also gave a high density product, a greater yield of minus 70 sieve size product, and an improved reconstitution quality. This may be attributed to starch changes within the potato cells of the moist-mixture. Potter (13) has discussed such changes in starch. Little or no benefit occurred if the tempering temperature was 140° F. Reduction below 60° F. did not show increasing benefits in one or two hours. Normally a tempering time of one hour was adequate for moist-mixtures of 37 to 39 per cent moisture at temperatures of 60° to 70° F.

Final mixing (Fluffing mix). A five-minute mix was used in the standardized procedure following the tempering period. This was used to separate any loose agglomerates that formed during the tempering period because of residual stickiness. It made the product easier to feed into the air-lift drier by reducing the tendency to bridge. This final mixing increased the yield of minus 70 sieve size granules. If the previous processing steps were properly carried out, no damage to the product resulted from the fluffing mix. Damage occurred during the final mixing if the cooling, secondary mixing, and tempering periods were inadequate, so that firm agglomerates did form.

Cooling, tempering, and mixing are difficult to discuss separately because of the related effects of time and temperature upon the moist-mixture. However, experimental data may be used to illustrate the importance of each. Table 6 compares the effect of rapid air cooling of the moist mixture immediately after mash-mixing with similar runs in which the air cooling was omitted. The effect of the air cooling and mixing as previously discussed gave increased yield of fine minus 70 mesh product without any increase in the Blue Value Index.

In other experiments, heated or cooled air was blown through the mixer. In one test with hot air the moist-mixture temperature was 83° F. and the Blue Value was 120. This was compared with a similar run using cold air to lower the temperature of the moist-mixture to 62° F., which gave a product with a Blue Value of 108. Blowing air over the moist mixture during tempering on trays reduced the Blue Value from 140 to 130 and increased the yield of the minus 70 fraction.

TABLE 6.—*Effects of air cooling the moist-mixture.*

Cooling	Product +40	Size 40-70	Classification —70	Density g./cc.	Blue Value Index
	Per cent	Per cent	Per cent		
Fast[1]	3	31	66	0.89	131
Slow[2]	10	43	47	0.87	131

[1]Air blown through and over the moist-mixture during second mixing.
[2]Cooled slowly in mixing bowl.

The effects of mixing and tempering schedules are shown in table 7. The control run in this experiment was mash-mixed for five minutes, cooled by air passing up through the moist-mixture, mixed five minutes both before and after one hour of tempering, and dried in the air-lift and fluidized-bed driers. The second run differed from the control by the omission of mixing immediately after cooling, but it had 10 minutes of mixing after tempering. The third run differed from the control by having 10 minutes of mixing following cooling but the after-tempering mix was omitted.. In the fourth run the one-hour tempering period was omitted but it had 10 minutes of mixing following cooling. Product from all runs was of excellent rehydration quality, but increased coarseness resulted from the modifications of the control procedure.

In another similar experiment, Kennebec potatoes were run under the third and fourth conditions of table 7. The product yield and color were similar to the above data. The cake diameters in the drop test were 62 and 61 mm., indicating less mealiness in the reconstituted product. The process was not varied from that used for Russet Burbank potatoes.

Coarseness of Add-back Material. The coarseness of the add-back granules, if they consist of loose agglomerates, need not affect either the process or the product. However, it should be mentioned that loose aggregates of reagglomerated cells are more easily damaged than the separated cells. If the former are used, the process must be adjusted to reduce agglomerate breakage while dry. Coarse material consisting of hardened unmashed material when used as add-back does not benefit the process. An experiment of several cycles was carried out to determine the effect of add-back coarsness on the product. In this experiment the coarseness was caused primarily by re-agglomeration. Initial mash-mixing was completed at a temperature of approximately 140° F. so that the add-back granules were warmed and moistened quickly; then mixer damage was minimal. The over-all results of this experiment (Table 8) indicated that coarser add-back material did not affect product quality.

Comparison of Tray and Air Suspension Drying on Particle Size Distribution. Although drying methods have been discussed to a considerable extent by Neel *et al.* (8) and Olson *et al.* (9, 10, 11, 12), further data were obtained on the effects of tray and air-suspension drying (Table 9). These data show an increase in coarseness or agglomeration when the moist material was not mixed by airflow during drying. During tray drying the particles rest in contact with one another and form loose agglomerates as they dry. Occasional stirring of the product on drying trays during initial drying reduced coarseness. Once the agglomerates dried together, their product quality decreased as the product was mixed to break them. Granule separation by air suspension gave a higher yield of fine product with no increase in damage when carried out in the air-lift dryer or in the fluidizing bed. Fluidized bed drying required a longer time and lower air temperatures than air-lift drying.

Color Control. The sugar content of the potatoes used plays a vital role in the color of finished product and in its storage life. Usually a discolored (browned) product has a scorched off-flavor. With low-sugar potatoes, the drying methods described above normally keep product temperature low enough to avoid serious darkening of the product during processing. The data in table 10 is included to indicate the effectiveness

TABLE 7.—*Effect of mixing and tempering schedules.*

Variables[1]	Blue Value Index	Drop Test Cake Dia. mm.	Yield Per cent		Color[3] Rd.
			+70	—70	
Control[2]	88	69	28	72	66
Mixed 10 min. after tempering	84	70	38	62	66
Mixed 10 min. before tempering	88	71	38	62	66
No tempering	101	67	43	57	65

[1]All samples were mash-mixed 5 minutes, fluidized bed cooled and had a total of 15 minutes' mixing.
[2]Mixed 5 minutes after cooling and again after tempering.
[3]Hunter instrument reading.

TABLE 8.—*Effect of coarseness of add-back granules.*

Add-back	Product Sieve Size[1]			Product Density g./cc.	Blue Value Index
	+40	40-70	—70		
Coarse[2]	5	29	66	0.88	134
Fine[3]	3	30	67	0.89	134

[1]Average size distribution over 8 cycles.
[2]Coarse add-back was 15 per cent +40, 85 per cent 40-70 mesh.
[3]Fine add-back was 100 per cent —70 mesh.

TABLE 9.—*Effect of drying methods on particle size.*[1]

Drying Cycle Number	Drying Method	Particle Size Distribution	
		+70	—70
		Per cent	Per cent
1	On Trays	79	21
3	"	84	16
5	"	84	16
8	"	83	17
1	Air Suspension	33	67
3	"	26	74
5	"	26	74
8	"	22	78

[1]Except for granule size other product qualities appeared equal.

of sodium bisulfite during the mash-mixing for color control. The potatoes in this experiment were from one lot and all processed by the standard method. The initial add-back granules used in these studies contained about 100 ppm. of sulfur dioxide by the method of Potter *et al* (14). Therefore, the full effect of reduced sulfite was not evident, since the original add-back material made up an appreciable part of the final product, even after 6 or 8 cycles. Levels higher than 150 ppm. did not appear to improve the color.

Preheating Potatoes Prior to Cooking. Placing peeled and cut potatoes in hot water (140 to 160° F.) for various lengths of time prior to cooking was observed to reduce sloughing, and if this treatment was prolonged, textural alterations were encountered, as reported by Cording *et al.* (3, 4) and Reeve (15, 16). The pieces were firmer and tougher than untreated pieces cooked under standard conditions. Longer cooking reduced the effect of the precooking heat treatment. Table 11 presents experimental data regarding the effect of the precooking heat treatment. The precooking heating benefited the process by reducing Blue Value Index and improving color. The drop test of the reconstituted mashed potatoes was similar to that of the control.

When the Blue Value Index procedure was altered by extracting at temperatures of 190° and 170° F., the potato granules produced from precooked heat-treated potatoes had lower soluble starch indexes as shown in table 12, indicating greater tolerance to high reconstitution temperatures.

Raw Materials. It has been observed that reconstituted potato granules often reflect many of the quality attributes of the fresh potatoes from which they are made. Therefore, the quality of the fresh mash may be used to estimate the quality of the potato granules that may be produced from them. Potatoes having a high solids content normally produce more and better-quality potato granules than do those of lower solids. In table 13 are presented data showing effects of specific gravity on quantity and quality of potato granules produced under standardized conditions from one lot of potatoes that had been sorted into 4 sub-lots by flotation in brines of graded specific gravity. This demonstrates the increased yield, better cell separation, higher product density, and better texture of product from the higher-gravity potatoes. Varied cooking time is required for different gravity potatoes. Extra add-back granules are required to obtain the same moisture content in the moist-mixture when using low solids potato.

In other experiments, parts of the same tubers were cut and separated. These parts, the less dense water-core area (center), and more dense cortex area (next to skin) were used to prepare potato granules. The higher solids cortex area yielded more and better potato granules than the central water-core area. Experiments using other potato varieties gave similar trends of increased yield and quality with increased specific gravity. California Long White (White Rose) and Russet Burbank potatoes, the dominant local market varieties, were used in laboratory sudies. Long storage or sprouting reduced tuber quality for granule production by increasing yellowness and decreasing mashing quality.

Summary

The use of unpeeled potatoes was observed to increase product yield,

TABLE 10.—*Effect of SO_2 on product color.*

SO_2 Content[1] ppm.	Reflectance Color[2]		
	Rd	a	b
10	60	—3.4	+18.2
88	62	—4.3	+17.2
129	64	—4.5	+17.3
145	67	—4.1	+19.2

[1]Average level over 6 or 8 cycles.
[2]Reflectance color by Hunter Color and Color Difference Meter.

TABLE 11.—*Effect of pre-cook heating.*

Pre-Cooking Treatment	Blue Value[2] Index	Reflected Color			Drop Test Cake Diameter
		Rd	a	b	mm.
Not heated	121	58	—2.6	+21.3	72
Heated[1]	68	61	—3.3	+20.6	71

[1]Heated 1½ hours in water 140-160° F.
[2]Blue Value Index on final product.

TABLE 12.—*Effect of pre-cooking heating on Blue Value Index of product.*

Pre-Cooking Treatment	Blue Value Index[1] at Different Temperatures		
	190° F.	170° F.	150° F.
Not heated	315	187	121
Heated[2]	197	118	68

[1]Blue Value Index on final product, extraction at indicated temperatures.
[2]Potatoes heated 1½ hours in water at 140° to 160° F. before cooking.

TABLE 13.—*Effects of specific gravity of raw material.*

Tuber Specific Gravity	Total Yield	Size Distribution[1]		Product Density	Texture Rank
		Coarse	Fine		
	Per cent	Per cent	Per cent	g./cc.	
Less than 1.074	15	1.3	86	0.90	4
1.074 - 1.084	18	0.9	87	0.91	3
1.084 - 1.090	19	0.8	90	0.92	2
Greater than 1.090	21	0.7	90	0.93	1

[1]Coarse: retained on 16-mesh screen, discarded. Fine: passes 70-mesh screen.
[2]Rank 1 = most mealy; rank 6 = least mealy (10 judges, 3 judgings, 6 samples).

darken color, and alter flavor of potato granules. Hot mash-mixing was the most successful mashing method developed for our equipment. Rapidly cooling the moist mixture immediately after mashing benefited the process. Mixing before and after tempering increased the yield of fine granules with no alteration of quality. Tempering reduced mechanical damage and improved quality of product. Precook heating and cooking procedures must be properly controlled, since they were found to affect the color, flavor, and texture of the final product. Over- or undercooking impaired product quality. The addition of sulfite was found necessary for good color control. Of the varieties used, those of higher specific gravity gave increased yield and better potato granules.

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AFTER-COOKING DARKENING IN OIL-BLANCHED FRENCH-FRIED POTATOES[1]

W. W. HAWKINS,[2] MARY E. G. CHIPMAN[3] AND VERNA G. LEONARD[3]

When potatoes turn dark during or after cooking there are two distinct color reactions involved. One is a browning reaction which occurs in potato chips or French-fried potatoes while they are being cooked in oil. It is associated with high temperatures, and the principal chemical factor in the reaction is due to the amount of reducing sugar (3, 18, 29). The other is the development of a grey color after potatoes have been boiled. The important chemical factors in this reaction are apparently tannins and other hydroxyphenyl compounds (2, 9, 10, 11, 12), and iron (9, 11, 12, 17). It is the second of these reactions, commonly referred to as "after-cooking darkening," which is the subject of this report.

This type of discoloration has recently created a problem for producers of a relatively new commercial product called oil-blanched French-fried potatoes. These are partially cooked French-fried potatoes, which are frozen immediately after preparation, and used in the restaurant trade. In the restaurant the cooking of the potato pieces is finished by deep-fat frying just before they are served. Prepared in this way, they more closely resemble fresh French-fried potatoes than do those which have been completely cooked as such, frozen, and then heated in an oven just before serving. The problem of after-cooking darkening was brought to our attention by McCain Foods, Ltd., East Florenceville, N. B. They had encountered it in the oil-blanched French-fried product from potatoes grown in New Brunswick in 1957. They reported that other processors had had the same experience with potatoes grown in Maine, but that it had not been encountered in potatoes from Idaho.

It is reasonable to suppose that climatic differences between these two parts of the continent could impose differences in the soil which could affect the chemistry of the potatoes in such a way as to bring about this difference. Smith (23) found that potatoes grown under conditions of low temperature and high soil moisture showed more after-cooking darkening than did those grown under hot and dry conditions.

Since hydroxyphenyl compounds (2, 9, 10, 11, 12) and iron (9, 11, 12, 17) have been implicated in the phenomenon as observed in boiled potatoes, we undertook to find whether they might be important factors in this case, and if so whether materials which immobilize or remove iron would deter the reaction.

MATERIALS AND METHODS

Two lots of potatoes grown in 1957 were examined. One was grown in the St. John River Valley in New Brunswick, and the other in Idaho. The exact location was not known in either case.

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Oil-blanched French-fried potatoes were prepared in the laboratory by a process similar to that used on a large scale by McCain Foods, Ltd. The potatoes were peeled, and cut into pieces of the typical size and shape of French-fried potatoes. They were then rinsed for 20 minutes in cold running tap water. Following this they were blanched for 5 minutes in water at 80° - 82° C., and drained. They were fried for 1 minute in corn oil which had been preheated to 190° C., after which they were drained, and assessed for flavor and color.

The concentrations of *o*-dihydroxyphenols (1, 15), tannins (19), total iron (21), and ionizable iron (7, 22) in the raw tubers were determined upon samples of potato pulp from each lot.

One of the New Brunswick potatoes was boiled for 5 minutes, and allowed to stand in the air for several hours. Dark and light portions were then taken from it, and their iron contents determined.

Some oil-blanched French-fried potatoes were prepared from samples of each of the two lots, and the iron contents of the products compared.

An experiment was conducted on the New Brunswick potatoes with various compounds which might immobilize or remove iron. Various acids, and ethylenediaminetetraacetic acid (EDTA) and its disodium salt were used. They were added to the water for blanching during the preparation of oil-blanched French-fried pieces, the procedure not being altered otherwise. The effects of these compounds upon the iron content and the color of the finished product were noted.

Results

The oil-blanched French-fried product from Idaho potatoes was cream to dark brown in color, and showed no greyish pigmentation. That from New Brunswick potatoes contained parts which were very dark grey, almost black, in color. Figure 1 illustrates this difference between the products from the two lots. They did not differ in flavor.

The figures in table 1 indicate that there were somewhat higher concentrations of *o*-dihydroxyphenyl compounds, tannins, and iron in the potatoes from New Brunswick than in those from Idaho, but the differences were too small to be considered significant. The great variation in the iron content of the tubers of both lots is noteworthy, because very likely it is a reflection of unevenness of distribution. It should also be noted, as shown in figure 1, that the darkening occurred in definitely localized portions of the potato pieces. Apparently the chromogenic materials were not evenly distributed throughout the tuber. Therefore, the distribution and not the level of active material is apparently the important factor, and that would not be indicated in expressions of concentration obtained from samples of potato pulp, as were those given in table 1.

The dark portion from the New Brunswick potato which had been boiled contained 0.74 mg. per cent iron, and the light portion 0.65 mg. per cent. Oil-blanched French-fried pieces from New Brunswick potatoes contained in a composite sample 1.22 mg. per cent iron, and those from Idaho potatoes 0.99 mg. per cent. After cooking, therefore, the typical small difference in iron content between the two lots was still apparent. The higher values compared with those from raw tubers (Table 1) can be attributed to shrinakge by loss of water during the cooking process.

FIGURE 1.—Oil-Blanched French-fried potatoes: 1. Idaho potatoes pre-blanched in water; 2. New Brunswich potatoes pre-blanched in water; 3. New Brunswick potatoes pre-blanched in o-phosphoric acid, pH 4; 4. New Brunswick potatoes pre-blanched in 1 per cent citric acid; 5. New Brunsswick potatoes pre-blanched in 0.1 per cent disodium EDTA.

TABLE 1.—*A comparison of some chemical characteristics of potatoes from New Brunswick and from Idaho.*

	New Brunswick				Idaho			
	o-Dihydroxy-phenols	Tannins	Total Iron	Ionizable Iron	o-Dihydroxy-phenols	Tannins	Total Iron	Ionizable Iron
	mg. Per cent							
Composite Sample from 5 Tubers	11.8	5.6			10.7	5.0		
Composite Sample from 3 Tubers	14.6	4.3			11.9	3.1		
Individual Values on 8 N. B. and 12 Idaho Potatoes, Ranges and Averages*			0.62-0.91 0.79*				0.45-0.89 0.62*	
Composite Sample from 8 Tubers			0.82				0.79	
Composite Sample from 8 Tubers				0.79				0.74

*$p < .01$

In table 1 the figures for the ionizable iron content of the potatoes indicate that this fraction was a large proportion of the total iron, about 95 per cent, which is in agreement with previous findings (Shackleton and McCance 22).

Table 2 summarizes the results of the experiment in which oil-blanched French-fried pieces were prepared from some of the New Brunswick potatoes, with acids or chelating compounds added to the water for blanching. *o*-Phosphoric or hydrochloric acid at pH 4 had no effect on the color of the product. Citric acid and the disodium salt of EDTA, both in 1 per cent solution, gave a product lighter in color than that of the Idaho potatoes put through the unmodified process. The acid EDTA in 1 per cent solution had some effect, but some grey spots appeared in the finished product. The levels of iron shown in table 2 for the finished products would suggest that no iron was removed by any of the materials which were added to the blanching water.

In another experiment some of the New Brunswick potatoes were treated with *o*-phosphoric acid at pH 4 for 30 minutes' blanching, but this did not prevent the appearance of dark grey spots in the finished product, and its iron content was 0.99 mg. per cent. In other trials various concentrations of citric acid and of disodium EDTA were used in the blanching water, and it was found that the lowest concentrations which prevented darkening were 1 per cent for citric acid and 0.1 per cent for disodium EDTA. Figure 1 shows the appearance of the oil-blanched French-fried potatoes when blanched in these solutions and also when blanched in *o*-phosphoric acid at pH 4. The product from untreated (blanched in water) New Brunswick potatoes and that from untreated Idaho potatoes are also shown. Blanching in 1 per cent citric acid or 0.1 per cent disodium EDTA prevented an objectionable degree of darkening in potatoes, which otherwise occurred when they were put through the ordinary process. The flavor of the product was not affected in either case.

Discussion

It was unexpected that blanching in *o*-phosphoric acid at pH 4 did not prevent the dark coloration in oil-blanched French-fried potatoes, because Smith *et al.* (24, 25) found that it was effective in preventing it in boiled potatoes, and recommended it as the best treatment for preventing the reaction.

The commercial use of citric acid or of disodium EDTA in 1 per cent and 0.1 per cent concentration, respectively, might pose a problem for disposal. A closely related point is the possible physiological effect of salts of EDTA if taken with food over a long period of time.

EDTA is a sequestering agent for many metals (20), and it has been used medically in the treatment of metal poisoning and hypercalcemia. For hypercalcemia the sodium salt has been given intravenously, mostly in repeated doses, and as much as 20 gm. have been given by slow injection at one time (4, 8). In such cases the blood serum calcium is lowered and the urinary excretion of calcium is increased (4). In the absence of hypercalcemia the slow infusion of relatively large doses does not affect the serum calcium level, but the urinary calcium is increased, which has been taken to indicate that there is mobilization from

TABLE 2.—*Color and iron content of oil-blanched French-fried pieces from New Brunswick potatoes when various compounds were added to the blanching water during their preparation.*

Solution for Blanching	Iron Content of Product, Mg. per cent	Color of Product
Water	1.00	Dark grey spots
o-Phosphoric Acid, pH 4	1.01	Dark grey spots
Hydrochloric Acid, pH 4	–	Dark grey spots
Citric Acid, 1 per cent	1.10	Light cream color, no dark spots
EDTA, 1 per cent	1.52	Light brown color, some light grey spots
Disodium EDTA, 1 per cent	1.22	Light cream color, no dark spots

the skeleton (26). Pathological changes have been seen in some cases after such treatment, most prominent among them being damage to renal tubules (4, 8).

The results of studies on rats and men have indicated that after parenteral injection, EDTA is excreted in the urine to the extent of 95-99 per cent (5, 6). After oral ingestion only a small fraction, 4 - 20 per cent, is absorbed (5, 6, 16), and the absorption is slow (5, 6). Rats have been given single oral doses as high as 4 gm. per Kg., and have been fed diets containing 0.5 per cent for a year without signs of toxicity appearing (14). From the ingestion of EDTA, however, there is the possibility of the chelation of nutritionally essential metals in the gastro-intestinal tract, which could result in deficiencies. If EDTA should come into use to an important extent in food processing or in the treatment of edible plants, this possibility should be considered, and more knowledge concerning it obtained.

If iron is involved in the after-cooking darkening of potatoes, the role of EDTA in preventing it can be explained. Because the iron salts of *o*-dihydroxyphenol compounds are greenish in color, it has been proposed that these compounds are responsible for the discoloration (11, 12). During our work on this problem we observed that the products of reaction between ferric chloride and dihydroxyphenylalanine and ferric chloride and tannic acid are greyish green in color, and resemble visually and spectrophotometrically the alcoholic extract of darkened cooked potato.

Most of the extractable iron of potatoes is in the ferrous state (17). Ferric iron forms complexes with many biological compounds with which ferrous iron does not (28). Darkened portions of potatoes contain more phenols than light portions (9). There is evidence that the oxidation of ferrous to ferric iron, and the reaction between the latter and *o*-dihydroxyphenyl compounds are involved in the darkening process (13, 15). The presence of air is important (13, 15, 17), and there is a marked increase in oxidase activity when the potato tuber is cut (27). In the

preparation of oil-blanched French-fried potatoes by McCain Foods, Ltd., the potato peeling is removed with steam. The pieces from the peripheral parts of the tubers so peeled do not darken during and after the cooking process. There is also more darkening in this semi-cooked product than in French-fried potatoes which are completely cooked. These suggest that heat-labile enzymes are involved in the reaction. All that is known about the process of after-cooking darkening in potatoes is consistent with the following explanation of it : When the tubers are cut in preparation for cooking, oxidative enzymes become much more active, ferrous iron is oxidized, and the ferric iron so produced reacts with *o*-dihydroxyphenyl compounds to form the dark pigments.

Summary

A lot of potatoes grown in New Brunswick, Canada, in 1957 contained on the average slightly more iron, *o*-dihydroxyphenyl compounds, and tannins than did a lot grown in Idaho in the same year, but the differences were not important. The measurements were made on potato pulp from composite samples.

Oil-blanched French-fried potatoes (a partially cooked product) prepared from the New Brunswick tubers showed dark grey spots, and those prepared from the Idaho tubers did not. Since the pigment appeared in localized portions of the product, it is suggested that the distribution and not necessarily the amount of chromogenic materials in the tubers, is important.

Blanching in 1 per cent citric acid or 0.1 per cent disodium ethylenediaminetetraacetate during preparation prevented discoloration in the finished product.

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NEWS AND REVIEWS

POTATO FLAKES CITED BY FOOD TECHNOLOGISTS

A new dehydrated mashed-potato product known as potato flakes, which was developed by the U. S. Department of Agriculture, was hailed May 18 at the annual meeting of the Institute of Food Technologists in Philadelphia.

The Institute's Food Technology Achievement Award went to the Eastern Utilization Research and Development Division of the Agricultural Research Service, in Wyndmoor, Pa. (near Philadelphia) and to three engineers, James Cording, Jr., Miles J. Willard, Jr., and Roderick K. Eskew.

The award recognizes the phenomenal success of potato flakes, which were first made commercially only a little over a year ago. Total production this season in the 7 plants where potato flakes are now being made should reach 25 million pounds. Nationwide distribution to the retail and institutional trade is rapidly being approached

The success of the new product is attributed to its ready acceptance by consumers. The housewife can convert flakes in a minute or two into fluffy mashed potatoes that are the equal of the fresh in flavor, color, and texture. She simply adds hot water and milk to the flakes, plus butter and salt as desired, and whip slightly.

The development has meant a great deal to agriculture, for it has provided potato growers with a new and profitable food outlet for their crops. And the benefit is not limited to those areas of the country where high-solids varieties are grown. The process is adaptable to potatoes of many varieties from many growing areas.

The flake process is simple. It consists essentially of drying freshly mashed potatoes on a drum drier such as is used in potato-flour plants. In about 20 seconds the potatoes come from the dryer in the form of a parchment-like sheet containing about 4½ to 5 per cent moisture. An attachment on the dryer cuts the sheet into flakes of the desired size for packaging.

An essential feature of the process is that the potatoes are precooked in water and cooled before they are steam-cooked and diced for application to the drum drier. These preliminary steps improve the texture of the mash and of the final product when it is converted back into mashed potatoes.

The principle of precooking and cooling discovered in the course of this development is not only applicable to flakes, but is important to the entire potato-processing industry as a means of controlling the physical properties of potato products.

The advent of this new product promises to boost consumption in this country. For the past 50 years Americans have been eating less and less potatoes, with frequently disastrous results to growers. One of the main deterrents to a wider consumption of potatoes has been the time and labor involved in preparing them—especially in their most popular form—mashed. Processed products such as chips, frozen French fries, and prepeeled potatoes have done much in recent years to reverse the declining trend of potato consumption, and the new potato flakes should do a great deal more to restore the potato to its former place of prominence in the American diet.

SILVER PLATE FOR POTATOES

C. J. Robb[1]

That the humble potato should have been served up in silver rings and dishes on the tables of the elite in Ireland may seem unique. The potato ring is essentially Irish in origin, the potato being once the national staple food of the Emerald Isle. It began to appear on the table of the nobility and gentry two centuries ago and consisted of a pierced sterling sliver ring, nine to twelve inches in diameter and from three ot five inches deep. It was made at first, to rest on a china plate containing potatoes in their jackets or skins. In the 1780s the baked potatoes were held in a silver dish with a blue glass lining.

The ring, here depicted, which measures almost seven inches in diameter, was made by W. Hughes, a Dublin silversmith in 1774 and is a good example. The Marquis of Ely, in this period, had two rings made, each sixteen inches in diameter and four inches deep. The ring was solid silver, ornated with designs of the potato root and crossed spades, for the root was cultivated with spades in those days. These rings had a silver bottom, lined with boxwood and baize covered to prevent the heat of the cooked potatoes from damaging the polished table. The insides were lined with red glass having a rope bead or lip which fitted down on the silver rim and was most effective.

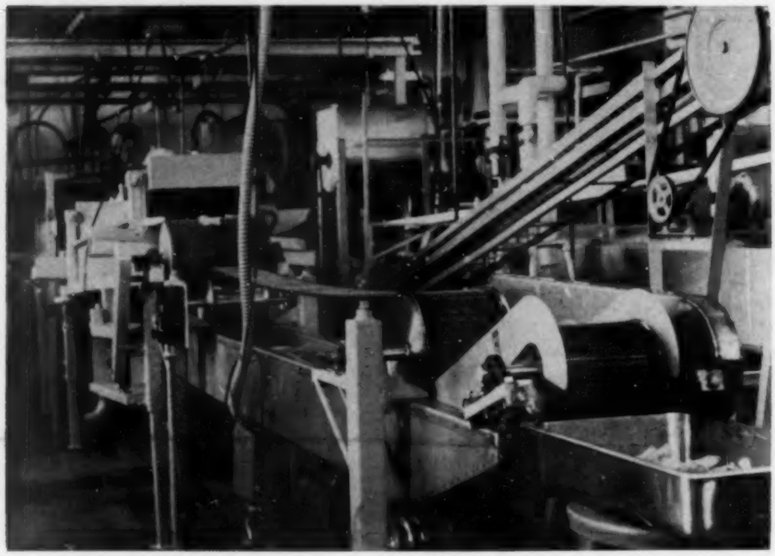
Early in the last century two potato plates, twelve inches in diameter, were made by a Cork silversmith. They were fashioned in silver like a deep soup plate and made of solid silver, having a white glass lining. So because of its importance the potato had its complement of silver on the tables of men of rank and fame in the days of long ago.

[1]Curio consultant, Timpany, County Down, Ireland.

OHIO GROWERS DONATE NEW TYPE FRYER FOR CHIP RESEARCH

The Ohio Potato Growers Association, Columbus, has purchased a potato chip fryer for the Department of Horticulture, Ohio State University, and Ohio Agricultural Experiment Station. The fryer, costing over two thousand dollars, was designed and constructed by the Scott-Viner Co., Columbus, well-known manufacturers of equipment for vegetable processors. The fryer was presented to the Department by R. E. Weingart, president of the state-wide Association.

The equipment has been installed in the Horticultural Products Laboratory at Ohio State University. Dr. W. A. Gould and his associates in the Horticultural Products Division will be responsible for the work in this area.



All parts of the fryer coming in contact with the potato slices are made of stainless steel, including the conveyor. It is also equipped with an electrical Chromalox heat exchanger for heating the frying oil which is circulated through it by a pump. The cooker portion is insulated with two inches of glass wool. The capacity of the machine has not been determined yet, but it will be placed in an assembly line type of operation.

This equipment, according to Gould, will increase the efficiency of staff members who have been using smaller equipment to fry the chip samples.

—*E. C. Wittmeyer*

IMPROVED PROCESSING HELPS WIDEN MARKETS FOR POTATO PRODUCTS, USDA REPORTS

Improvements to help widen the markets for potatoes were reported by U. S. Department of Agriculture scientists at the 10th Annual Potato Utilization Conference at Idaho Falls, Idaho.

The improvements include:

1. An experimental method of controlling blistering of potato chips —often a serious problem in the $500 million potato-chip industry.
2. A manufacturing change that eliminate the need, in making potato granules, of adding previously dried granules to undried potato mash.
3. Changes in making potato flakes (another dehydrated potato product) that reduce the chance that flakes may develop a pasty quality, permit denser packing of flakes than was previously possible, and insure long-life on restaurant and cafeteria steam tables.

The blister control and granule processing reports were made by C. E. Hendel of the Agricultural Research Service's Western Utilization Research and Development Division at Albany, Calif., and the potato flake report by Roderick K. Eskew of the ARS Eastern Utilization Research and Development Division at Wyndmoor, Pa., where potato flakes were developed.

Blistering of chips, Mr. Hendel said, can be controlled by heating the raw potato slices in water or a weak solution of a calcium salt at 130 to 150° F. for four to five minutes before the slices are fried.

The granule improvement involves first cooking the raw potatoes, to induce granulation, mashing the potatoes while they are still cold, and partially drying them on heated drums, holding them at a low temperature finally drying them in a stream of hot air. This sequence does away with the need for adding previously dried granules to undried mash. The process has been tried on laboratory scale equipment, but further work is necessary to adapt it to commercial operations.

The potato flake processing steps outlined by Mr. Eskew include precooking potato slices for about 20 minutes at 165° F., then cooling them in water before steam cooking. He explained that, in manufacturing any dried mashed potato product, many of the starch-containing cells are likely to be ruptured, and the soluble starch thus released causes the product to become pasty. Precooking gelatinizes the starch granules and weakens cell-cementing material, so that mashing can be done with a minimum of cell breakage. Cooling the pre-cooked slices makes the gelatinized starch insoluble so that, even if some of it is released by broken cells, it does not cause pastiness.

Packaging efficiency is realized because the modified procedure allows the potato flakes to be cut into much smaller particles than they used to be, without sacrificing the excellent texture of the product. Institutional users of potato flakes will benefit because of the length of time that reconstituted mashed potatoes keep their fluffy texture on steam tables.

The developments are all outgrowths of integrated programs of basic, applied, and developmental research at the ARS Western and Eastern laboratories.

The dehydrated potato industry now processes about 5 per cent of all potatoes used for food.

REINER BONDE

Dr. Reiner Bonde, widely known plant pathologist of the University of Maine, Orono, since 1924, pased away in his sleep Monday, July 13 at Presque Isle, Maine. He was 63 years of age.

Dr. Bonde was widely known for his research in the control of potato diseases. He first identified bacterial ring rot in Maine, discovered how it was spread and developed methods for its control. He has also developed many ring rot resistant varieties.

His work with control measures for virus diseases has been a prime factor in the development of the huge seed potato certification program in Maine and the State Seed Board Farm where high quality seed stock is produced for Maine seed growers. Reiner Bonde was the first to discover that potato cull piles were a primary source of late blight infection in Maine and developed methods to prevent its spread. He has tested hundreds of fungicides for late blight control and was responsible for the blight control measures recommended in Maine for many years.

Dr. Bonde had been a member of the Potato Association of of America for many years and had served as its Secretary and President.

He was elected an Honorary Life Member of the Association in 1957 in recognition of his outstanding contribution to the potato industry.

He was also a member of the American Phytopathological Society, the American Botanical Society, and the American Association for the Advancement of Science.

The science of Plant Pathology and the potato industry of Maine have lost a valuable scientist and the potato growers of Maine a devoted friend.

We extend our sympathy to his wife and family.

ERRATUM

The co-author of the article "A simplified method of isolating single cells of streptomyces" is L. W. Durrell not L. W. Dirrell as printed in Volume 36, No. 4, page 137.

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